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Harvey, Jeffrey A.; Heinen, Robin; Armbrrecht, Inge; Basset, Yves; Baxter-Gilbert, James H.; Bezemer, T. Martijn; Böhm, Monika; Bommarco, Riccardo; Borges, Paulo A.V.; Cardoso, Pedro; Clausnitzer, Viola; Cornelisse, Tara; Crone, Elizabeth E.; Dicke, Marcel; Dijkstra, Klaas Douwe B.; Dyer, Lee; Ellers, Jacintha; Fartmann, Thomas; Forister, Mathew L.; Furlong, Michael J.

published in

Nature Ecology and Evolution

2020

DOI (link to publisher)

[10.1038/s41559-019-1079-8](https://doi.org/10.1038/s41559-019-1079-8)

document version

Publisher's PDF, also known as Version of record

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citation for published version (APA)

Harvey, J. A., Heinen, R., Armbrrecht, I., Basset, Y., Baxter-Gilbert, J. H., Bezemer, T. M., Böhm, M., Bommarco, R., Borges, P. A. V., Cardoso, P., Clausnitzer, V., Cornelisse, T., Crone, E. E., Dicke, M., Dijkstra, K. D. B., Dyer, L., Ellers, J., Fartmann, T., Forister, M. L., ... de Kroon, H. (2020). International scientists formulate a roadmap for insect conservation and recovery. *Nature Ecology and Evolution*, 4(2), 174-176.
<https://doi.org/10.1038/s41559-019-1079-8>

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International scientists formulate a roadmap for insect conservation and recovery

To the Editor — A growing number of studies are providing evidence that a suite of anthropogenic stressors — habitat loss and fragmentation, pollution, invasive species, climate change and overharvesting — are seriously reducing insect and other invertebrate abundance, diversity and biomass across the biosphere^{1–8}. These declines affect all functional groups: herbivores, detritivores, parasitoids, predators and pollinators. Insects are vitally important in a wide range of ecosystem services⁹ of which some are vitally important for food production and security (for example, pollination and pest control)¹⁰. There is now a strong scientific consensus that the decline of insects, other arthropods and biodiversity as a whole, is a very real and serious threat that society must urgently address^{11–13}. In response to the increasing public awareness of the problem, the German government is committing funds to combat and reverse declining insect numbers¹³. This funding should act as a clarion call to other nations across the world — especially wealthier ones — to follow suit and to respond proactively to the crisis by addressing the known and suspected threats and implementing solutions.

We hereby propose a global ‘roadmap’ for insect conservation and recovery (Fig. 1). This entails the immediate implementation of several ‘no-regret’ measures (Fig. 1, step 1) that will act to slow or stop insect declines. Among the initiatives we encourage are the following immediate measures:

Taking aggressive steps to reduce greenhouse gas emissions; reversing recent trends in agricultural intensification including reduced application of synthetic pesticides and fertilizers and pursuing their replacement with agro-ecological measures; promoting the diversification and maintenance of locally adapted land-use techniques; increasing landscape heterogeneity through the maintenance of natural areas within the landscape matrix and ensuring the retention and creation of microhabitats within habitats which may be increasingly important for insects during extreme climatic events such as droughts or heatwaves; reducing identified local threats such as light, water or noise pollution, invasive species and so on; prioritizing the

import of goods that are not produced at the cost of healthy, species-rich ecosystems; designing and deploying policies (for example, subsidies and taxation) to induce the innovation and adoption of insect-friendly technologies; enforcing stricter measures to reduce the introduction of alien species, and prioritizing nature-based tactics for their (long-term) mitigation; compiling and implementing conservation strategies for species that are vulnerable, threatened or endangered; funding educational and outreach programs, including those tailored to the needs of the wider public, farmers, land managers, decision makers and conservation professionals; enhancing ‘citizen science’ or ‘community science’ as a way of obtaining more data on insect diversity and abundance as well as engaging the public, especially in areas where academic or professional infrastructure is lacking; devising and deploying measures across agricultural and food value chains that favour insect-friendly farming, including tracking, labelling, certification and insurance schemes or outcome-based incentives that facilitate behavioural changes, and investing in capacity building to create a new generation of insect conservationists and providing knowledge and skills to existing professionals (particularly in developing countries).

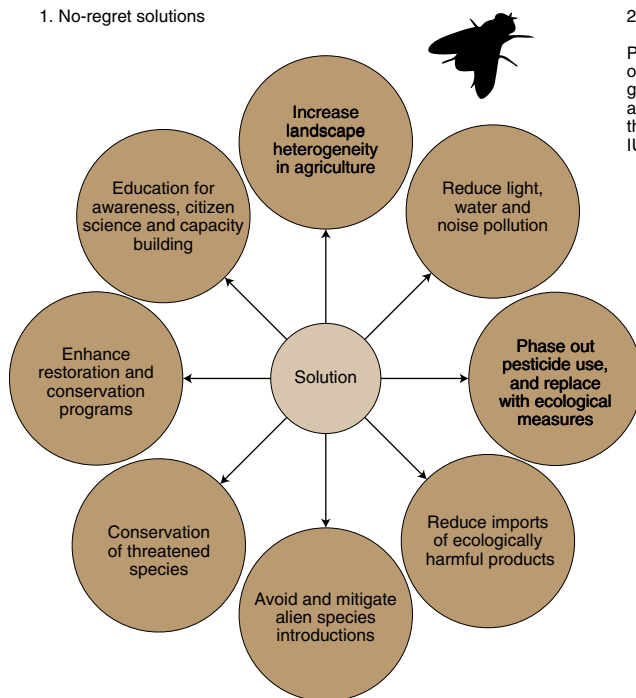
To better understand changes in insect abundance and diversity, research should aim to prioritize the following areas:

Quantifying temporal trends in insect abundance, diversity and biomass by extracting long-term datasets from existing insect collections to inform new censuses; exploring the relative contributions of different anthropogenic stressors causing insect declines within and across different taxa; initiating long-term studies comparing insect abundance and diversity in different habitats and ecosystems along a management-intensity gradient and at the intersection of agricultural and natural habitats; designing and validating insect-friendly techniques that are effective, locally relevant and economically sound in agriculture, managed habitats and urban environments; promoting and applying standardized monitoring protocols globally and establishing long-term monitoring plots or sites based on such protocols, as well as increasing support for existing monitoring

efforts; establishing an international governing body under the auspices of existing bodies (for example, the United Nations Environment Programme (UNEP) or the International Union for Conservation of Nature (IUCN)) that is accountable for documenting and monitoring the effects of proposed solutions on insect biodiversity in the longer term; launching public–private partnerships and sustainable financing initiatives with the aim of restoring, protecting and creating new vital insect habitats as well as managing key threats; increasing exploration and research to improve biodiversity assessments, with a focus on regional capacity building in understudied and neglected areas, and performing large-scale assessments of the conservation status of insect groups to help define priority species, areas and issues.

Most importantly, we should not wait to act until we have addressed every key knowledge gap. We currently have enough information on some key causes of insect decline to formulate no-regret solutions whilst more data are compiled for lesser-known taxa and regions and long-term data are aggregated and assessed. Implementation should be accompanied by research that examines impacts, the results of which can be used to modify and improve the implementation of effective measures. Furthermore, such a ‘learning-by-doing’ approach ensures that these conservation strategies are robust to newly emerging pressures and threats. We must act now. □

Jeffrey A. Harvey ^{1*}, Robin Heinen ¹, Inge Armbrrecht ², Yves Basset ³, James H. Baxter-Gilbert ⁴, T. Martijn Bezemer ¹, Monika Böhm ⁵, Riccardo Bommarco ⁶, Paulo A. V. Borges ⁷, Pedro Cardoso ⁸, Viola Clausnitzer ⁹, Tara Cornelisse ¹⁰, Elizabeth E. Crone ¹¹, Marcel Dicke ¹², Klaas-Douwe B. Dijkstra ¹³, Lee Dyer ¹⁴, Jacintha Eilers ¹⁵, Thomas Fartmann ¹⁶, Mathew L. Forister ¹⁴, Michael J. Furlong ¹⁷, Andres Garcia-Aguayo ¹⁸, Justin Gerlach ¹⁹, Rieta Gols ¹², Dave Goulson ²⁰, Jan-Christian Habel ²¹, Nick M. Haddad ²², Caspar A. Hallmann ²³, Sérgio Henriques ²⁴, Marie E. Herberstein ²⁴, Axel Hochkirch ²⁵, Alice C. Hughes ²⁶, Sarina Jepsen ²⁷, T. Hefin Jones ²⁸, Bora M. Kaydan ²⁹, David Kleijn ³⁰, Alexandra-Maria Klein ³¹,

Immediate action**1. No-regret solutions****2. Prioritization**

Perform large-scale assessments of the conservation status of insect groups to define priority species, areas and issues, for example increase the number of insects with informative IUCN Red List assessments.

Mid-term action**3. New research**

Conduct new research to disentangle the contributions of different anthropogenic stressors driving insect declines, within and across different taxa. Perform field studies along a management-intensity gradient and at the intersects of agricultural and natural habitats. Increase explorative research to accelerate rate of knowledge gain in understudied areas.

4. Existing data

Analyse current data on insect diversity that is present, such as in private, museum and academic insect collections. This is important to form new censuses of past insect diversity. This is especially important in areas where scientific data currently do not exist.

Long-term action**5. Partnerships**

Launch public–private partnerships and sustainable financing initiatives with the aim of restoring, protecting and creating new vital insect habitats, as well as managing key threats.

6. Global monitoring program

Promote and apply standardized monitoring protocols at a global level under the auspices of an existing international governing body (for example, the UN or IUCN). Establish standardized sites where monitoring is conducted over longer terms. Ensure support for existing monitoring efforts.

Fig. 1 | Roadmap to insect conservation and recovery, calling for action at short-, intermediate- and long-term timescales. No-regret measures for immediate utilization in insect conservation refer to actions that should be implemented as soon as possible. These solutions will be beneficial to society and biodiversity even if the direct effects on insects are not known as of yet (that is, no-regret solutions). This encompasses utilization of insect-friendly techniques that are effective, locally relevant and economically sound, for example, in farming, habitat management and urban development.

Tanya Latty³², Simon R. Leather³³, Sara M. Lewis³¹, Bradford C. Lister³⁴, John E. Losey³⁵, Elizabeth C. Lowe²⁴, Craig R. Macadam³⁶, James Montoya-Lerma³⁷, Christopher D. Nagano¹⁰, Sophie Ogan²⁵,

Michael C. Orr³⁸, Christina J. Painting³⁹, Thai-Hong Pham⁴⁰, Simon G. Potts⁴¹, Aunu Rauf⁴², Tomas L. Roslin⁶, Michael J. Samways⁴³, Francisco Sanchez-Bayo⁴⁴, Sim A. Sar⁴⁵, Cheryl B. Schultz⁴⁶, António O. Soares⁴⁷,

Anchana Thancharoen⁴⁷, Teja Tscharntke⁴⁸, Jason M. Tylianakis⁴⁹, Kate D. L. Umbers⁵⁰, Louise E. M. Vet¹, Marcel E. Visser⁵¹, Ante Vujic⁵¹, David L. Wagner⁵², Michiel F. WallisDeVries⁵³,

Catrin Westphal⁵⁴, Thomas E. White³²,
Vicky L. Wilkins⁵⁵, Paul H. Williams⁵⁶,
Kris A. G. Wyckhuys⁵⁷, Zeng-Rong Zhu⁵⁸
and Hans de Kroon²³

¹Netherlands Institute of Ecology (NIOO-KNAW), Wageningen, The Netherlands. ²Departamento de Biología, Universidad del Valle, Cali, Colombia. ³ForestGEO, Smithsonian Tropical Research Institute, Panama City, Panama. ⁴Centre for Invasion Biology, Stellenbosch University, Matieland, South Africa. ⁵Institute of Zoology, Zoological Society of London, London, UK. ⁶Department of Ecology, Swedish University of Agricultural Sciences, Uppsala, Sweden. ⁷CE3c-Centre for Ecology, Evolution and Environmental Changes / Azorean Biodiversity Group, University of Azores, Lisbon, Portugal. ⁸Laboratory for Integrative Biodiversity Research (LIBRe), Finnish Museum of Natural History, University of Helsinki, Helsinki, Finland. ⁹Senckenberg Research Institute, Goerlitz, Germany. ¹⁰Center for Biological Diversity, Portland, OR, USA. ¹¹Department of Biology, Tufts University, Medford, MA, USA. ¹²Laboratory of Entomology, Wageningen University, Wageningen, The Netherlands. ¹³IUCN SSC Freshwater Conservation Committee, Naturalis Biodiversity Center, Leiden, The Netherlands. ¹⁴Biology Department, University of Nevada, Reno, NV, USA. ¹⁵Department of Ecological Sciences, Vrije University, Amsterdam, The Netherlands. ¹⁶Department of Biodiversity and Landscape Ecology, Osnabrück University, Osnabrück, Germany. ¹⁷School of Biological Sciences, The University of Queensland, St Lucia, Queensland, Australia. ¹⁸Estacion de Biología Chamela, Instituto de Biología, Chamela, Jalisco, Mexico. ¹⁹IUCN SSC Terrestrial Invertebrate Red List Authority, Cambridge, UK. ²⁰School of Life Sciences, University of Sussex, Brighton, UK. ²¹Evolutionary Zoology, Department of Biosciences, University of Salzburg, Salzburg, Austria. ²²Kellogg Biological Station and Department of Integrative Biology, Michigan State University, Hickory Corners, MI, USA. ²³Institute for Water and Wetland Research, Radboud University, Nijmegen, The Netherlands.

²⁴Department of Biological Sciences, Macquarie University, Sydney, New South Wales, Australia. ²⁵Department of Biogeography, Trier University, Trier, Germany. ²⁶Centre for Integrative Conservation, Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, Menglun, Yunnan, China. ²⁷The Xerces Society for Invertebrate Conservation, Portland, OR, USA. ²⁸School of Biosciences, Cardiff University, Cardiff, UK. ²⁹Biotechnology Application and Research Centre, Çukurova University, Balcali, Adana, Turkey. ³⁰Plant Ecology and Nature Conservation Group, Wageningen University, Wageningen, The Netherlands. ³¹Albert Ludwigs University of Freiburg, Freiburg, Germany. ³²School of Life and Environmental Science, Sydney Institute of Agriculture, University of Sydney, Sydney, New South Wales, Australia. ³³Crop & Environment Science, Harper Adams University, Newport, UK. ³⁴Department of Biological Sciences, Rensselaer Polytechnic Institute, Troy, NY, USA. ³⁵Entomology Department, Cornell University, Ithaca, NY, USA. ³⁶Buglife - The Invertebrate Conservation Trust, Peterborough, UK. ³⁷Departamento de Biología, Universidad del Valle, Cali, Colombia. ³⁸Key Laboratory for Zoological Systematics and Evolution, Institute of Zoology, Chinese Academy of Sciences, Beijing, China. ³⁹School of Science, University of Waikato, Hamilton, New Zealand. ⁴⁰Vietnam National Museum of Nature & Graduate School of Science and Technology, Vietnam Academy of Science and Technology, Hanoi, Vietnam. ⁴¹Centre for Agri-Environmental Research, School of Agriculture, Policy and Development, Reading University, Reading, UK. ⁴²Department of Plant Protection, IPB University, Bogor, Indonesia. ⁴³Department of Conservation Ecology and Entomology, Stellenbosch University, Matieland, South Africa. ⁴⁴Department of Environment and Energy, Canberra, Australian Capital Territory, Australia. ⁴⁵National Agricultural Research Institute, Lae, Papua New Guinea. ⁴⁶School of Biological Sciences, Washington State University, Vancouver, British Columbia, USA. ⁴⁷Department of Entomology, Faculty of Agriculture, Kasetsart

University, Bangkok, Thailand. ⁴⁸Agroecology, Department of Crop Sciences, University of Göttingen, Göttingen, Germany. ⁴⁹Bio-protection Centre, School of Biological Sciences, University of Canterbury, Christchurch, New Zealand. ⁵⁰School of Science and Health, Western Sydney University, Penrith, New South Wales, Australia. ⁵¹Department of Biology and Ecology, Faculty of Sciences, University of Novi Sad, Novi Sad, Serbia. ⁵²Ecology and Evolutionary Biology, University of Connecticut, Storrs, CT, USA. ⁵³De Vlinderstichting (Dutch Butterfly Conservation) & Plant Ecology and Nature Conservation Group, Wageningen University, Wageningen, The Netherlands. ⁵⁴Functional Agrobiodiversity, Department of Crop Sciences, University of Göttingen, Göttingen, Germany. ⁵⁵IUCN SSC Mid Atlantic Island Invertebrate Specialist Group, IUCN, Cambridge, UK. ⁵⁶Natural History Museum, London, UK. ⁵⁷Chrysalis Consulting, Hanoi, Vietnam. ⁵⁸Zhejiang Provincial Key Laboratory of Crop Insect Pests and Diseases, Hangzhou, Zhejiang, China.
*e-mail: j.harvey@nioo.knaw.nl

Published online: 6 January 2020
<https://doi.org/10.1038/s41559-019-1079-8>

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Competing interests

The authors declare no competing interests.